Ocean Mixing and Strait Dynamics

Chris Garrett
Department of Physics and Astronomy
Elliott Building
University of Victoria
P.O. Box 3055
Victoria, BC
Canada, V8W 3P6
Phone: 250-721-7702 Fax: 250-721-7715 Email: garrett@phys.uvic.ca

Award Number: N00014-03-1-0400
http://maelstrom.seos.uvic.ca/

LONG-TERM GOALS

To understand and parameterize interior and near-boundary mixing processes in the ocean.

To understand the physical oceanography of straits and semi-enclosed seas.

OBJECTIVES

One objective is to use data from nearby Juan de Fuca Strait and the Arctic to understand the influence of small-scale topography on stratified flow and to evaluate mixing rates.

I also seek to determine the role of friction, entrainment and shear on flow within straits and to use new results to improve models relating strait exchange to the properties of semi-enclosed seas.

APPROACH

For the last several summers we have conducted observational studies in Juan de Fuca Strait involving one or more bottom-mounted 300 kHz broadband ADCPs, temperature and conductivity moorings, and CTD profiles and "towyos". Senior Research Associate Richard Dewey assumes much of the responsibility for this, with involvement of graduate and summer students. A current emphasis is on strong stratified shear flow past an isolated feature.

These studies have led to general analysis of ADCP and CTD data and the development of new concepts in data analysis and theory. With ADCP data, graduate student Steve Stringer has extended Reynolds stress analyses to allow for small instrument tilts. With CTD data, postdoctoral fellow Helen Johnson is investigating the effect of noise on Thorpe scale analysis. This has particular application to studies of vertical mixing processes in the Canada Basin in the Arctic Ocean.

On a different topic, graduate student Tetjana Ross, working largely with Rolf Lueck but with my input on some theoretical issues, has investigated models of temperature-salinity cospectra at very small scales, with consequences for acoustic backscatter from turbulence.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2003**	2. REPORT TYPE	3. DATES COVERED **00-00-2003 to 00-00-2003**

4. TITLE AND SUBTITLE **Ocean Mixing and Strait Dynamics**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Department of Physics and Astronomy,,Elliott Building,University of Victoria,P.O. Box 3055,,Victoria, BC,Canada, V8W 3P6, ,**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**7**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Investigation of strait flows has mainly involved posing and resolving theoretical questions concerning the effects on hydraulic control of entrainment, frictional processes and shear.

For semi-enclosed seas, information can be obtained from the frequency dependence of the response to forcing by different constituents. This is a joint project with Mike Foreman of the Institute of Ocean Sciences and summer student Graig Sutherland.

WORK COMPLETED

On a cruise in Juan de Fuca Strait in June 2002 we focused on a study of the effect on flow and mixing of an isolated bump with a scale of order a kilometre, rising 70 metres above the sea floor in water of depth 100 metres. Particularly on the ebb tide, undisturbed stratified water flows past and over the bump with a speed of about 2 metres per second. We moored two ADCPs in the lee (Figure 1) and conducted extensive CTD and shipboard ADCP surveys. Considerable analysis of this data set has been completed.

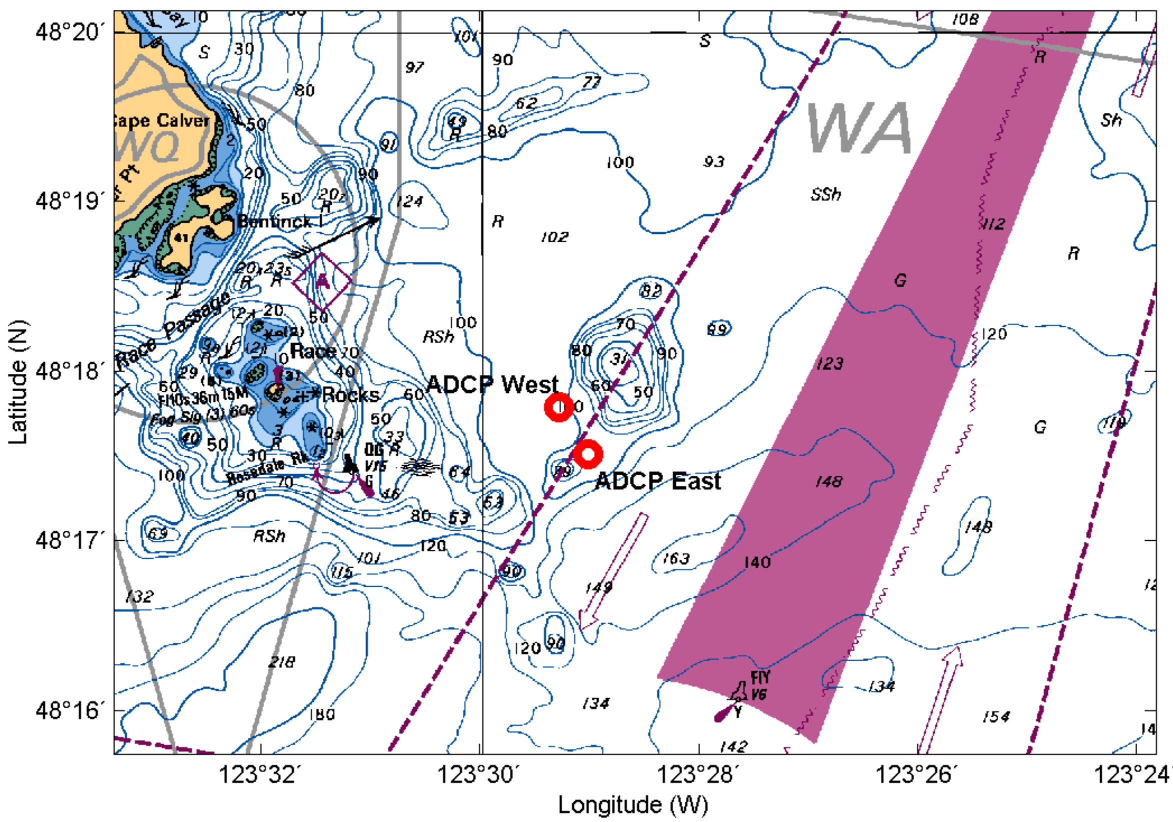

Figure 1. An isolated bump in the strong stratified tidal flows in Juan de Fuca Strait. The location of moored ADCPs is shown.

An analysis of the effects of pitch and roll on ADCP Reynolds stress estimates has been completed. A theory for Thorpe displacement run lengths in noise-dominated CTD data has been extended to allow for finite data length and sampling interval.

A new model for turbulent temperature-salinity cospectra has been developed.

A general theory has been completed to show how vertical shear and internal friction shift the location of hydraulic control in a homogeneous fluid.

An analysis of the frequency-dependent tidal response of the inland sea between Washington State and British Columbia has been completed. Also, new results have been obtained on the potential of tidal currents for power generation.

RESULTS

Flow past the bump shown in Figure 1. In particular, the data from the two bottom-mounted ADCPs show the effects of flow separation in the lee of the bump, and large short-range differences in upwelling and downwelling.

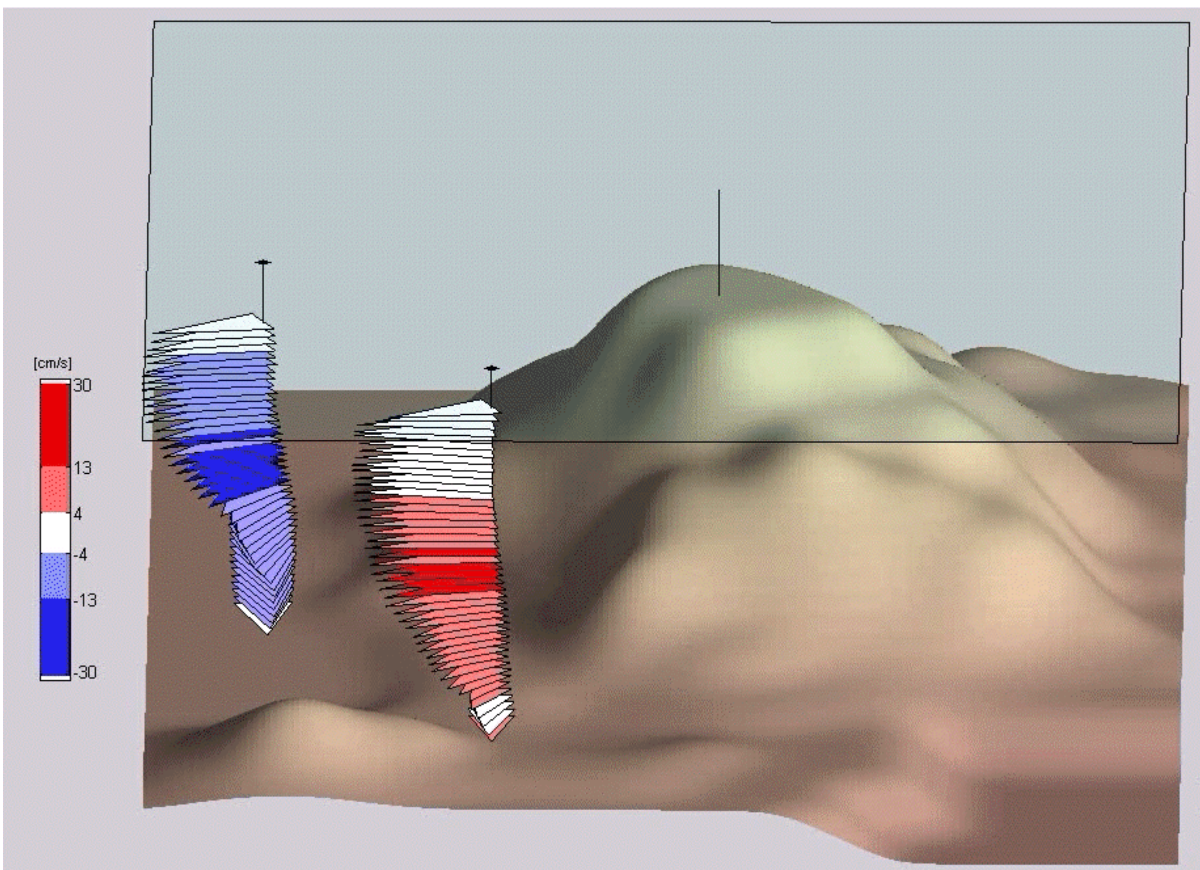

Figure 2. A sample frame from a movie made of the strong stratified flow past an isolated bump in Juan de Fuca Strait. The horizontal components of flow at the two bottom-mounted ADCPs are shown as hodographs, with the vertical component color-coded.

Vertical Reynolds stress measurements using the beam variance technique can be compromised by the almost inevitable small tilt angles of a mooring. M.Sc. student Steve Stringer has shown how the correction terms are best estimated, and, using a data set from the turbulent waters of Sansum Narrows, has shown that the correction can be effective.

Postdoctoral fellow Helen Johnson has shown that the expected run length for noise-induced Thorpe fluctuations drops dramatically from the theoretical value of 2.45 as the sampling interval increases. In the Arctic, however, we have obtained strong confirmation that the signals in double diffusive interfaces in the deep Canada Basin (Figure 3) are noise rather than signal, confirming that the geothermal heat flux must escape near the lateral boundaries.

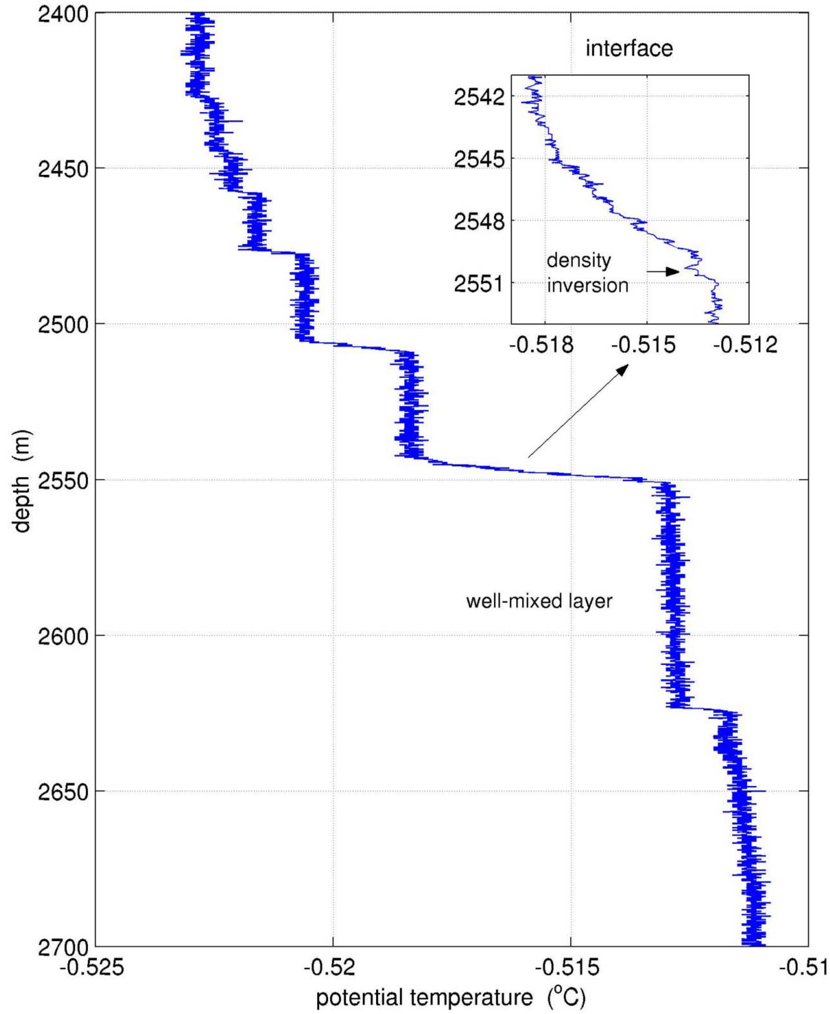

Figure 3. The temperature profile through a double-diffusive interface in the deep Canada Basin raises the question as to whether the fluctuations are noise or indications of turbulent mixing.

Work with Ph.D. student Tetjana Ross (mainly supervised by Rolf Lueck) has led to a novel theory for the co-spectrum of turbulent temperature and salinity fluctuations. The theory lacks the internal contradictions of previous approaches and has implications for acoustic scattering at high frequencies.

In a new theoretical approach to the hydraulics of a homogeneous fluid with shear and internal as well as bottom friction, I have shown that the downstream shift of the control section is reduced from that for a slab flow.

A “black box” tidal analysis of the Strait of Georgia, Puget Sound and Juan de Fuca Strait, using TOPEX/Poseidon data to represent offshore forcing, has shown that the resonant period is about 17 to 20 hours, and more importantly, that the system’s Q is only 2.2. This provides strong evidence that numerical models need to allow for more drag than typical, probably to allow for lateral form drag.

Proposals to exploit tidal currents for electricity generation have been compared with schemes involving large barriers. It has been shown that a significant fraction of the power available from a bay may be obtained without major disruption of the natural regime, essentially by shifting the phase of the tide in the bay rather than reducing its amplitude.

IMPACT/APPLICATIONS

Our results on strong stratified flow past an isolated bump should lead to improved parameterization of the associated drag and mixing.

Results on tilt corrections of Reynolds stress estimates will help with the establishment of reliable values and hence lead to improved parameterization.

Thorpe scale analysis is a promising technique for global mapping of diapycnal mixing. Our results will help in efforts to discriminate between noise and signal and narrow the error bars on mixing estimates.

Results on the temperature-salinity co-spectrum will be relevant to acoustic scattering in some oceanic regimes.

The new results on hydraulic flows with internal friction and shear should provide an intuitive basis for understanding real exchange flows.

As well as interaction with U.S. colleagues at the University of Washington, Oregon State University, Scripps and Woods Hole, I co-convened, with Peter Müller, the thirteenth ’Aha Huliko’a Hawaiian Winter Workshop, sponsored by ONR. I also gave the invited review talk on mixing at the WOCE and Beyond meeting in November 2002, and this year have written invited News and Views and Perspective commentaries for Nature and Science, respectively.

RELATED PROJECTS

The projects described above are also supported by Canadian funding agencies with equal or greater contributions to salaries and equipment and full provision of ship time.

PUBLICATIONS

St. Laurent, L. and C. Garrett. 2002. The role of internal tides in mixing the deep ocean. *J. Phys. Oceanogr.*, 32, 2882-2899. [published, refereed]

Ott, M. W., R. Dewey and C. Garrett. 2002. Reynolds stresses and secondary circulation in a stratified rotating shear flow. *J. Phys. Oceanogr.*, 32, 3249-3268. [published, refereed]

Müller, P. and C. Garrett. 2002. From stirring to mixing in a stratified ocean. *Oceanography*, 15, 12-19. [published, refereed]

Garrett, C. 2002. Tidal power generation by continuous flow. *Can. Appl. Math. Quarterly.* [in press, refereed]

Garrett, C. 2002. Frictional processes in straits. *ONR Villefranche Straits Workshop,* 17-24. [published]

Garrett, C. and F. Gerdes. 2003. Hydraulic control of homogeneous shear flows. *J. Fluid Mech., 475, 163-172.* [published, refereed]

St. Laurent, L., S. Stringer, C. Garrett, and D. Perrault-Joncas. 2003. The generation of internal tides at abrupt topography. *Deep-Sea Research I,* 50, 987-1003. [published, refereed]

Garrett, C. 2003. Frictional processes in straits. *Deep-Sea Res.II.* [in press, refereed]

Timmermans, M.-L., C. Garrett, and E. Carmack. 2003. The thermohaline structure and evolution of the deep waters in the Canada Basin, Arctic Ocean. *Deep-Sea Res. I.* [in press, refereed]

Garrett, C. and P. Cummins. 2003. Generating tidal power from currents. *J. Port, Coastal and Ocean Engineering.* [in press, refereed]

Garrett, C. 2003. Mixing with latitude. *Nature,* 422, 477-478. [published]

Garrett, C. 2003. Do near-boundary processes control the ocean? *Proceedings of the Thirteenth 'Aha Huliko'a Hawaiian Winter Workshop*. [in press]

Müller, P. and C. Garrett. 2003. Near-boundary processes and their parameterization. *Oceanography*.

Garrett, C. 2003. Internal tides and ocean mixing. *Science,* 301, 1858-1859. [published]

Sutherland, G., C. Garrett, and M. Foreman. 2003. Tidal resonance in Juan de Fuca Strait and the Strait of Georgia. *J. Phys. Oceanogr.*

HONORS/AWARDS/PRIZES

Chris Garrett, University of Victoria, Fellow, American Meteorological Society, 2003.